



DECLARATION

I, Tadashi UEDA, a subject of Japan residing at 1994-152, Hazama-cho, Hachioji-shi Tokyo 193-0941 Japan, solemnly and sincerely declare:

That I have thorough knowledge of Japanese and English languages; and

That the attached pages contain a correct translation into English of the specification of the following Japanese Patent Application:

APPLICATION NUMBER

11-111298

DATE OF APPLICATION

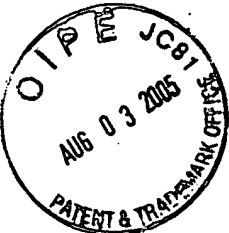
April 19, 1999

I hereby declare that all statements made herein of my own knowledge are true, and that all statements made on information and belief are believed to be true; and further, that these statements are made with the knowledge that willful false statements and the like so made, are punishable by fine or imprisonment, or both, under Section 1001, Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Signed this 10th day of June, 2005

Tadashi Ueda

Tadashi UEDA



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JP Application No. 11-111298

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[Application Fees]

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[List of Documents Attached]

[Name of Document] Specification 1

[Name of Document] Drawings 1

[Name of Document] Abstract 1

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[Proof]

Required

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[Name of Document] SPECIFICATION

[Title of the Invention] METHOD FOR MANUFACTURING
EXTERNAL FORCE DETECTION SENSOR

[Claims]

[Claim 1] A method for manufacturing an external force detection sensor in which sensor elements are formed by through dry etching of an element substrate,

wherein a conductive material is used for an etching stop layer to be used in the dry etching of the element substrate.

[Claim 2] A method for manufacturing an external force detection sensor comprising the steps of: forming a recessed part on the back face of the central area of an element substrate, and also forming a membrane on the front face; providing an etching stop layer composed of an electroconductive material on the top face of the recessed part of the element substrate; joining the back face of the element substrate with a support substrate; and forming sensor elements by dry etching the membrane of the element substrate.

[Claim 3] A method for manufacturing an external force detection sensor in which sensor elements are formed by through dry etching of an element substrate,

wherein an etching stop layer composed of a conductive material is interposed between the element substrate and a

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dummy support substrate supporting the element substrate.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to a method for manufacturing an external force detection sensor such as an angular velocity sensor, an acceleration sensor and a pressure sensor.

[0002]

[Description of the Related Art]

As an example of the conventional method for manufacturing an external force detection sensor, a method for manufacturing an angular velocity sensor will be described with reference to Figs. 10 to 14.

[0003]

In Fig. 10, numeral 1 denotes an element substrate composed of a single-crystal silicon board. Dry etching technology such as RIE (reactive ion etching) is used for forming a rectangular recessed part 1a in the central part of the back face of the element substrate 1, as well as a membrane 1b with a thickness of 20 to 30 μm on the top face of the recessed part 1a.

[0004]

In Fig. 11, an etching stop layer 2a composed of silicon oxide is provided on the top face of the recessed

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part 1a of the element substrate 1, using a film deposition means such as CVD (chemical vapor deposition).

[0005]

In Fig. 12, a support substrate 3 composed of a Pyrex glass board is anode-coupled to the back face of the element substrate 1.

[0006]

In Fig. 13, sensor elements of an angular velocity sensor 10 shown in Fig. 15 are formed by dry-etching the membrane 1b of the element substrate 1, by means of photolithography and RIE. The sensor elements include fixed electrodes 4a, 5a, fixed comb-teeth electrodes 3b and 3c, a vibrator 21, etc. Numeral 4b denotes etching slots formed between the fixed comb-teeth electrode 3b or 3c, and the vibrator 21. Numeral 5b denotes rectangular etching holes formed in the vibrator 21.

[0007]

In Fig. 14, the etching stop layer 2a is removed by means of wet etching using a buffer hydrofluoric acid aqueous solution. This allows movable parts such as the vibrator 21 to vibrate freely on the recessed part 1a.

[0008]

Next, the structure of the angular velocity sensor 10 will be described with reference to Fig. 15.

Numeral 21 denotes a rectangular vibrator representing

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a load mass for the angular velocity sensor 10, and is provided with two rectangular etching holes 5b inside. On the end faces of four peripheral sides, a plurality of number of movable electrodes 2b, 2c, 2d and 2e are formed respectively.

[0009]

In addition, from the four corners of the vibrator 21, four beams 2f bent in an L-shape are extended to be connected with fixed parts 2g. These fixed parts 2g are formed on the four corners of the support substrate 3. Thus, the vibrator 21 is supported by the fixed parts 2g over these four beams 2f, and is freely vibratable in the X and Y directions by virtue of the flexure of these beams 2f.

[0010]

Further, movable electrodes 2b to 2e are each meshed with fixed electrodes 3b to 3e through a gap, thus the movable electrode 2b and the fixed electrode 3b form a capacitor 4. A capacitor 5 is also formed by the movable electrode 2c and the fixed electrode 3c. A capacitor 6 is also formed by the movable electrode 2d and the fixed electrode 3d. Further, a capacitor 7 is formed by the movable electrode 2e and the fixed electrode 3e. It is noted that the fixed electrodes 3b to 3e are each connected with the rectangular fixed parts 4a, 5a, 6d and 7e formed in the center of the four peripheral areas of the support

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substrate 3.

[0011]

The above-described vibrator 21, the movable electrodes 2b to 2e, and the beams 2f constitute the movable parts of the angular velocity sensor 10, while the fixed parts 2g, the fixed electrodes 3b to 3e and the fixed parts 4a, 5a, 6d and 7e constitute the fixed parts of the angular velocity sensor 10.

[0012]

Next, the operation of the angular velocity sensor 10 shown in Fig. 15 will be described. The operation is executed with the fixed parts 2g grounded. Therefore, the vibrator 21 as well as the movable electrodes 2b to 2e are also grounded.

[0013]

A voltage is applied to the capacitor 4 and the capacitor 5 alternately to make the vibrator 21 vibrate in the X-axis direction by the electrostatic attracting force. While the vibrator 21 is vibrating in this manner, if the angular velocity sensor 10 rotates on the Z-axis passing through the center of the vibrator 21, the vibrator 21 starts to vibrate also in the Y-axis direction due to the Coriolis force caused by this rotational force. The vibrational component in this Y-axis direction is detected by the capacitors 6 and 7 as a change in the capacitance.

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The change in the capacitance is converted to a voltage, and then is differentially amplified to obtain an angular velocity.

[0014]

[Problems to be Solved by the Invention]

However, in the conventional method for manufacturing an angular velocity sensor 10 as an external force detection sensor, different etching rates will occur depending on the differences in size of the holes to be etched, due to the microloading effect when the element substrate 1 is dry-etched to form sensor elements such as the vibrator 21 as shown in Fig. 13. That is, etching holes 5b having a larger size are through etched more rapidly, and etched slots 4b having a smaller size are through etched more slowly. All the etching times, therefore, are adjusted to the maximum etching time for the hole/slot having the smallest size, for example, the etching time for the etching slots 4b.

[0015]

In etching the etching slots 4b and the etching holes 5b, some of the electrons in the etching gas except those going straight will irradiate the side walls of the etching slots 4b and the etching holes 5b. The side walls of the etching slots 4b and the etching holes 5b are negatively (-) charged as shown in Fig. 13. In addition, the positive

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ions will charge the etching stop layer 2a positively (+) when the etching has progressed to penetrate the etching slots 4b and the etching holes 5b, and subsequently has reached the etching stop layer 2a. And if the etching is continued onto the etching stop layer 2a, straight-going positive ions in the etching gas are repelled by the positive charges on the positively charged etching stop layer 2a, and are also attracted by the negative charges on the negatively charged etching slots 4b and the etching holes 5b, so that they are bent to irradiate the side surface parts of the etching slots 4b and the etching holes 5b contacting the etching stop layer 2a, thus forming notches n. When these notches n are formed, the front and back faces of the sensor element parts are not formed in an equivalent shape, and it is not possible to manufacture an external force detection sensor with stable output sensitivity.

[0016]

Thus, an object of the present invention is to provide a method for manufacturing an external force detection sensor with stable output sensitivity, by preventing the formation of notches caused by the etching gas.

[0017]

[Means for Solving the Problems]

The invention described in claim 1 is a method for

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manufacturing an external force detection sensor in which sensor elements are formed by through dry etching of an element substrate, wherein a conductive material is used for an etching stop layer to be used in the dry etching of the element substrate.

[0018]

According to this invention, holes with different diameters or slots with different widths are formed at the same time in the through dry etching of an element substrate. The rate of dry etching varies depending on the differences in size of the holes or slots. With a hole or slot having a larger size, the rate of dry etching is increased to complete the through-etching more rapidly than with a hole or slot having a smaller size due to the microloading effect.

[0019]

However, since the whole etching must be continued until the holes or slots with a smaller size are penetrated, sensor element parts that should be protected from irradiation of the dry etching gas during the period, tend to be damaged by the exposure to the etching gas intruding through such penetrated large holes or slots. The etching stop layer covering the sensor elements is, therefore, necessary to prevent these sensor element parts from being damaged by the etching gas.

[0020]

The etching gas used in the dry etching includes plasmatized electrons, positive ions, etc. This etching gas etches etching holes and slots vertically, and finally through-etches the holes and slots to reach the etching stop layer. In etching the etching holes and slots, some of the electrons in this etching gas except those going straight will irradiate the side walls of the etching holes and slots, thus causing the side walls of the etching holes and slots to be negatively charged. In addition, the positive ions in the etching gas will charge the etching stop layer positively when the etching has progressed to penetrate the etching holes and slots, and subsequently has irradiated the etching stop layer. And, when the etching is continuously performed on the etching stop layer, straight-going positive ions in the etching gas are repelled by the positive charges on the positively charged etching stop layer, and are also attracted by the negative charges on the negatively charged etching holes and slots, so that they are bent to irradiate the side surface parts of the etching holes and slots contacting the etching stop layer and, thus forming notches.

[0021]

This invention aims to prevent the formation of notches caused by this etching. In order to prevent

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positive charging of the etching stop layer which is usually formed of an insulating material such as an oxidized silicon film, the etching stop layer is formed of a conductive material for preventing. This conductive etching stop layer plays a role to rapidly neutralize the negative charges accumulated on the side walls of the etching holes and slots and the positive charges accumulated on the etching stop layer. Therefore, the etching stop layer composed of the conductive material neutralizes the charges of the positive ions in the etching gas irradiating the etching stop layer, with the result that the bending of the irradiation track of the positive ions in the etching gas is prevented in the etching holes and slots and therefore, the formation of notches can be prevented.

[0022]

The invention described in claim 2 includes the steps of: forming a recessed part on the back face of the central area of an element substrate, and also forming a membrane on the front face; providing an etching stop layer composed of a conductive material on the ceiling part of the recessed part of the element substrate; joining the back face of the element substrate with a support substrate; and forming sensor elements by dry-etching the membrane on the element substrate.

[0023]

In this invention, in forming sensor elements by dry-etching the membrane on the top face of a recessed part provided on an element substrate, if dry-etching has progressed, and subsequently the etching holes and slots have reached the conductive etching stop layer, the etching stop layer neutralizes the positively charged ions in the etching gas to prevent the bending of the irradiation track of the positive ions, so that no notches are formed on the bottom parts of the side walls of the etching holes and slots.

[0024]

The invention described in claim 3 is a method for manufacturing an external force detection sensor in which sensor elements are formed by through dry etching of an element substrate, wherein an etching stop layer composed of a conductive material is interposed between the element substrate and a dummy support substrate supporting the element substrate.

[0025]

In this invention, the etching stop layer composed of the conductive material is interposed between the element substrate and the dummy support substrate and the element substrate is through-etched. When the etching has progressed to penetrate the etching holes and slots, and

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subsequently the irradiation positive ions have reached the etching stop layer, the irradiation positive ions are neutralized by the etching stop layer. Therefore, no notches are formed on the bottom parts of the side walls of the etching holes and slots.

[0026]

[Description of the Embodiments]

A method for manufacturing an angular velocity sensor 10 shown in Fig. 15 will be described below, as a first embodiment of the method for manufacturing an external force detection sensor according to the present invention, in the same way as for the conventional examples.

[0027]

In Fig. 1, numeral 1 denotes an element substrate composed of single-crystal silicon. A rectangular recessed part 1a is formed in the center of the back face of the element substrate 1, and a membrane 1b with a thickness of $50\ \mu$ is formed on the top face of this recessed part 1a, using a dry etching technology such as RIE (reactive ion etching).

[0028]

In Fig. 2, an etching stop layer 2 composed of aluminum with a thickness of about 200 nm is formed on the top face of the recessed part 1a of the element substrate 1 by a deposition means such as vapor deposition or

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sputtering. Besides aluminum, a conductive material, for example, a metal such as nickel or copper, or a conductive resin, may be used for the etching stop layer 2.

[0029]

In Fig. 3, a support substrate 3 composed of a Pyrex glass board is anode-coupled to the back face of the element substrate 1.

[0030]

In Fig. 4, sensor elements of the angular velocity sensor 10 are formed as shown in Fig. 15 by dry-etching the membrane 1b of the element substrate 1 by means of photolithography and RIE. The sensor elements include fixed electrodes 4a, 5a, fixed comb-teeth electrodes 3b and 3c, a vibrator 21, etc. Furthermore, numeral 4b denotes etching slots formed between fixed comb-teeth electrode 3b or 3c, and a vibrator 21. Numeral 5b denotes rectangular etching holes formed in the vibrator 21.

[0031]

In Fig. 5, the etching stop layer 2 composed of aluminum is removed by wet etching by means of a hydrofluoric acid aqueous solution. By virtue of this, movable parts such as the vibrator 21 become freely vibratable on the recessed part 1a.

[0032]

In this embodiment, as shown in Fig. 4, in forming

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sensor elements by dry etching the membrane 1b of the element substrate 1, even if through-etching of the etching slots 4b and the etched holes 5b has progressed, and subsequently the positive ions in the etching gas have reached the etching stop layer 2 composed of aluminum, the irradiated ions are neutralized by aluminum due to its conductivity. Therefore, since the etching slots 4b, the etching holes 5b and the etching stop layer 2 (aluminum) are not charged by the irradiation positive ions, thus, the track of the irradiation positive ions is not bent. Thus, the bottom parts of the side walls of the etching slots 4b and the etched holes 5b are not affected by the irradiation of ions, and no notches are formed.

[0033]

Also, even if the etching holes 4b and the etching slots 5b are penetrated, the recessed part 1a does not suffer any damage due to exposure to the etching gas, since the etching gas is isolated by the etching stop layer 2. This etching stop layer 2 plays a role of protecting the sensor element parts from the intruding etching gas, as long as it is adhered to the back face of the sensor element parts, even if the layer is partially damaged to allow the etching gas to intrude into the recessed part 1a.

[0034]

Next, the method for manufacturing an angular velocity

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sensor according to a second embodiment of the present invention will be described with reference to Figs. 6 to 9.

[0035]

In Fig. 6, an etching stop layer 12 composed of thick aluminum with a thickness of 200 nm as a conductive material is deposited on the back face of an element substrate 11 composed of silicon by means of sputtering method.

[0036]

In Fig. 7, the element substrate 11 is adhered, on the side of the etching stop layer 12 as a surface for adhesion, to a dummy support substrate 13, using a photoresist 14 as an adhesive.

[0037]

In Fig. 8, sensor elements 11a to 11c are formed by dry-etching the element substrate 11 by means of photolithography and RIE. Numeral 11d denotes etching slots formed between the sensor elements 11a and 11c. Numeral 11e denotes etching holes formed in the sensor element 11c.

[0038]

In this process, in forming sensor elements 11a to 11c by dry-etching the element substrate 11, if through-etching of the etching slots 11d and the etching holes 11e has progressed, and subsequently the positive ions in the

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etching gas have reached the etching stop layer 12 composed of aluminum, the irradiated ions are neutralized by the aluminum due to its conductivity. Therefore, since the aluminum (etching stop layer 2) at the bottoms of the etching slots 11d and etching holes 11e are not charged by the irradiation positive ions, thus the track of the irradiation positive ions is not bent. Thus, the bottom parts of the side walls of the etching slots 11d and the etching holes 11e are not affected by the irradiation of ions, and no notches are formed.

[0039]

Next, in Fig. 9, the work shown in Fig. 8 is dipped in an acetone solution to dissolve the photoresist 14 to separate the sensor elements 11a to 11c (including the etching stop layer 12) from the dummy support substrate 13. Then, the sensor elements 11a to 11c (including the etching stop layer 12) are dipped in a hydrofluoric acid aqueous solution to remove the etching stop layer 12 by etching.

[0040]

In this embodiment, the element substrate 11 is adhered, on the side of the etching stop layer 12 as a surface for adhesion, to the support substrate 13, using a photoresist. By using a conductive adhesive such as a conductive resin as the etching stop layer, the element substrate can be adhered directly to the dummy support

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substrate. Accordingly, it is not necessary to use a conductive metal such as aluminum.

[0041]

[Advantages]

In the invention described in claim 1, since a conductive material is used for the etching stop layer, the positive ions in the etching gas are neutralized rapidly, the irradiation track of the positive ions is not bent, and accordingly there are no notches formed, so that the sensor element parts having equivalent cross-sections on both the front and back faces can be formed, which allow the manufacturing of an external force detection sensor with stable detection sensitivity.

[0042]

In the invention described in claim 2, there will be no notches formed on the bottom parts of the side walls of the etching holes and slots by the irradiation of etching gas. Therefore, the sensor element parts having equivalent cross-sections on both the front and back faces can be formed, which allow the manufacturing of an external force detection sensor with stable detection sensitivity.

[0043]

According to the invention described in claim 3, there will be no notches formed on the bottom parts of the side walls of the etching holes and slots by the irradiation of

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etching gas. Therefore, the sensor element parts having equivalent cross-sections on both the front and back faces can be formed, which allow the manufacturing of an external force detection sensor with stable detection sensitivity.

[Brief Description of the Drawings]

[Fig. 1] Fig. 1 shows a first embodiment of a method for manufacturing an external force detection sensor according to the present invention, and is a process drawing of forming a recessed part and a membrane by the etching work of an element substrate.

[Fig. 2] Fig. 2 is a process drawing of forming an etching stop layer in the recessed part of the element substrate.

[Fig. 3] Fig. 3 is a process drawing of anode-coupling an element substrate to a support substrate.

[Fig. 4] Fig. 4 is a process drawing of forming sensor elements by the etching work of the membrane of the element substrate.

[Fig. 5] Fig. 5 is a process drawing of removing an etching stop layer by etching.

[Fig. 6] Fig. 6 shows a second embodiment of a method for manufacturing an external force detection sensor according to the present invention, and is a process drawing of forming an etching stop layer on an element substrate.

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[Fig. 7] Fig. 7 is a process drawing of adhering an element substrate to a dummy support substrate on the side of the etching stop layer.

[Fig. 8] Fig. 8 is a process drawing of forming sensor elements by the etching work of the element substrate.

[Fig. 9] Fig. 9 is a process drawing of removing a photoresist, a dummy support substrate and an etching stop layer from the sensor elements.

[Fig. 10] Fig. 10 shows a conventional method for manufacturing an external force detection sensor, and is a process drawing of forming a recessed part and a membrane by working an element substrate.

[Fig. 11] Fig. 11 is a process drawing of forming an etching stop layer in the recessed part of the element substrate.

[Fig. 12] Fig. 12 is a process drawing of anode-coupling the element substrate to a support substrate.

[Fig. 13] Fig. 13 is a process drawing of forming sensor elements by working a membrane of the element substrate.

[Fig. 14] Fig. 14 is a process drawing of removing the etching stop layer by etching.

[Fig. 15] Fig. 15 is a plan view of an angular velocity sensor manufactured by a method for manufacturing an external force detection sensor according to either of the present invention or the conventional invention.

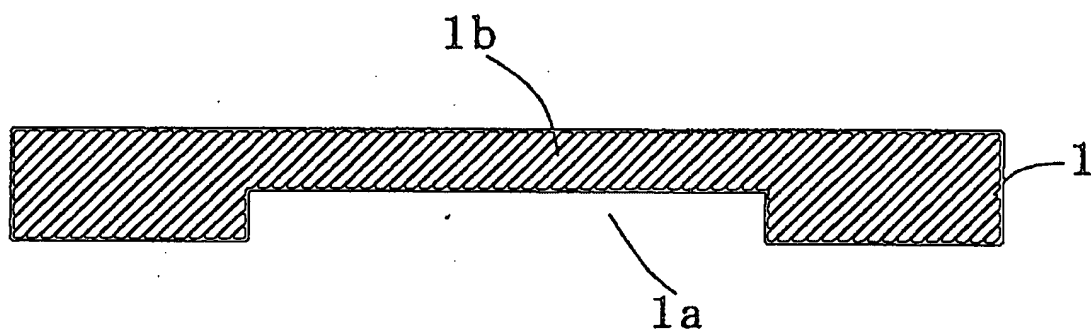
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[Reference Numerals]

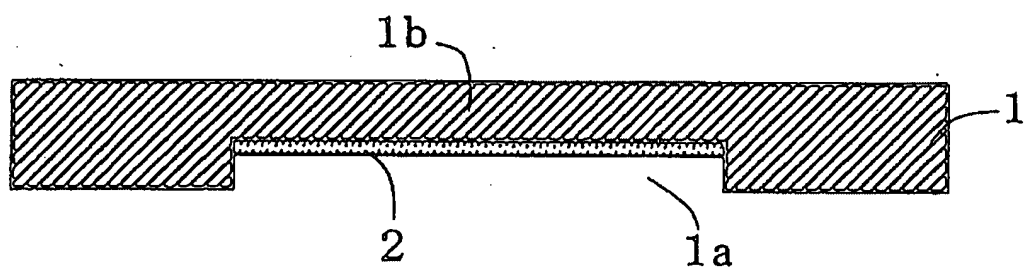
1, 11	element substrate
1a	recessed part
1b	membrane
2, 12	etching stop layer
3, 13	support substrate
3b, 3c	fixed comb-teeth electrode
4a, 5a	fixed electrode
4b, 11d	etching slot
5b, 11e	etching hole
11a to 11c	sensor element
14	photoresist
21	vibrator

【書類名】 図面 [Name of Document] DRAWINGS

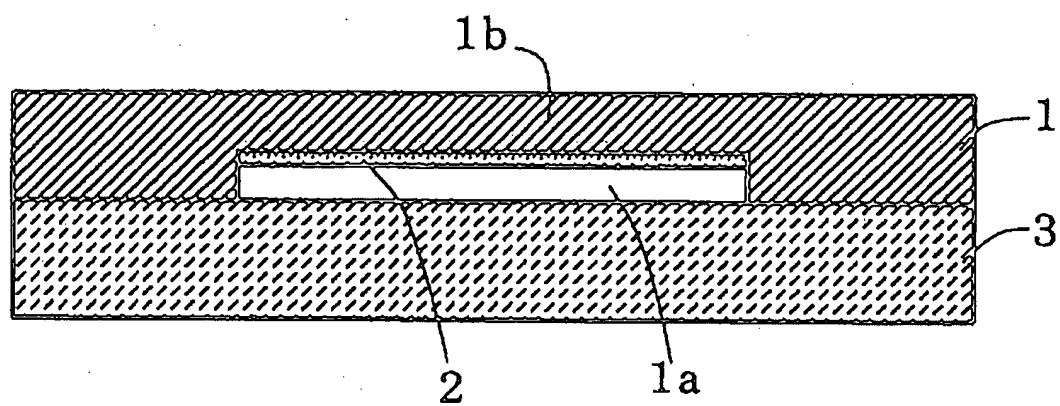
【図 1】 [FIG. 1]



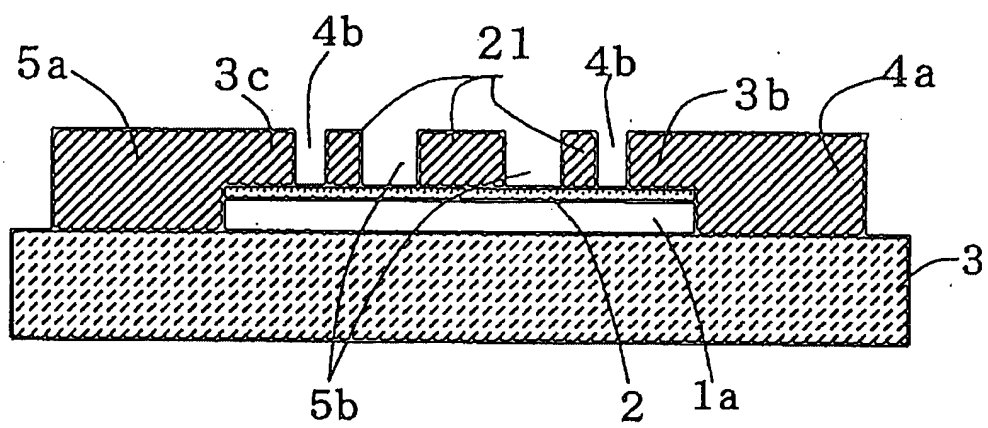
【図 2】 [FIG. 2]



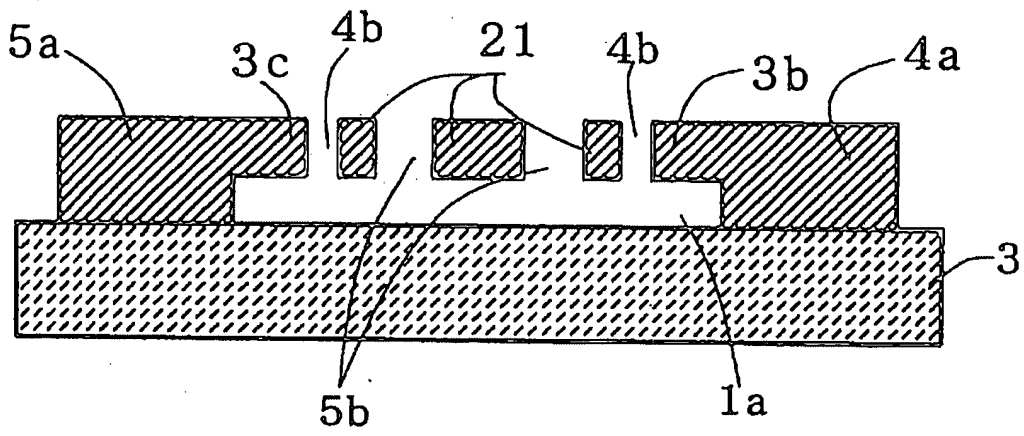
【図 3】 [FIG. 3]



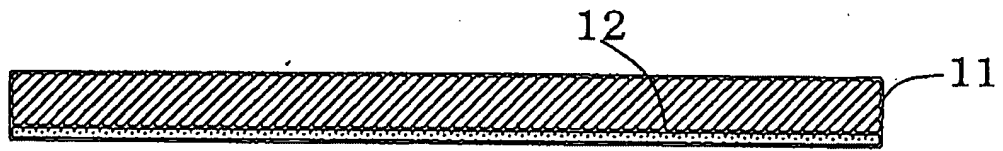
【図4】 [FIG. 4]



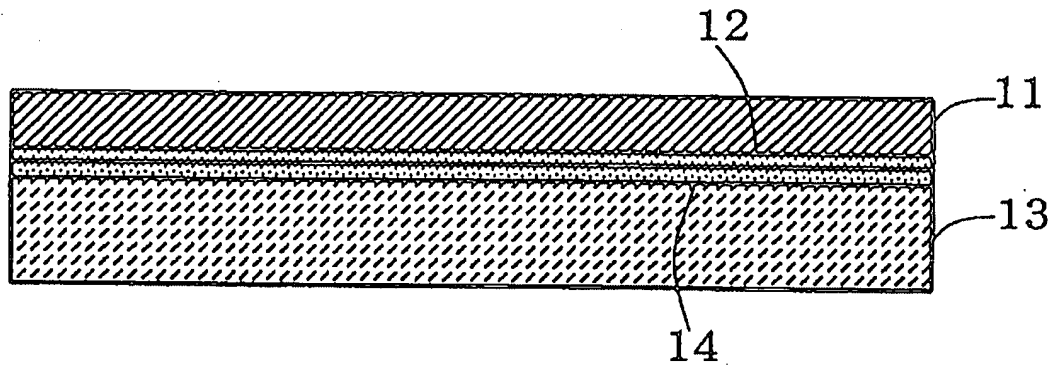
【図 5】 [FIG. 5]



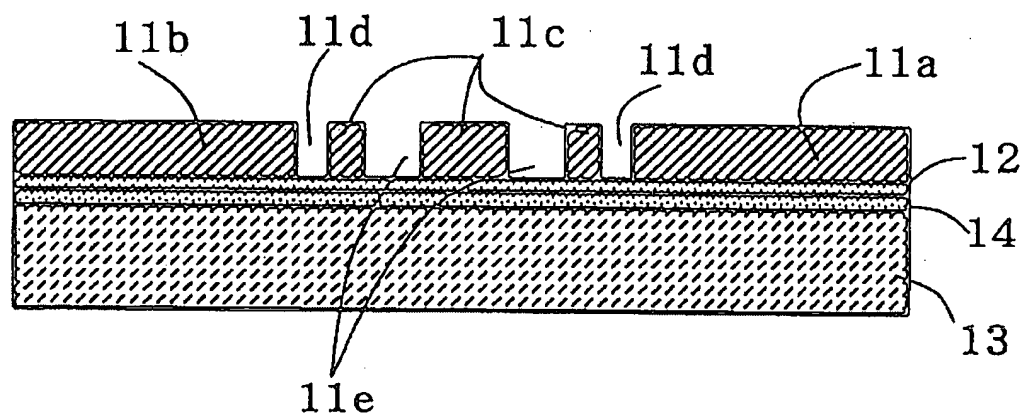
【図 6】 [FIG. 6]



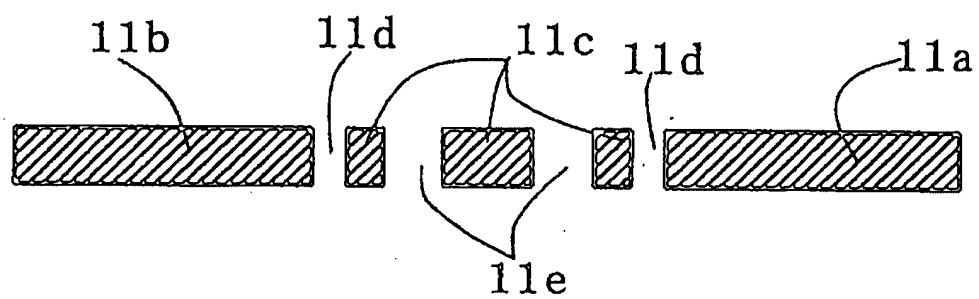
【図 7】 [FIG. 7]



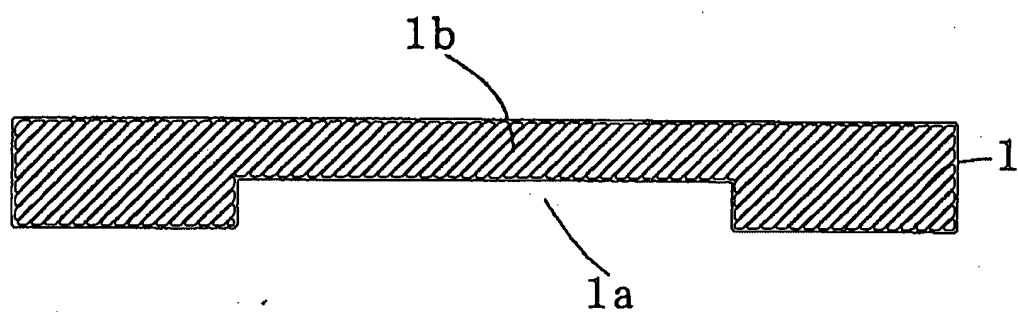
【図8】 [FIG. 8]



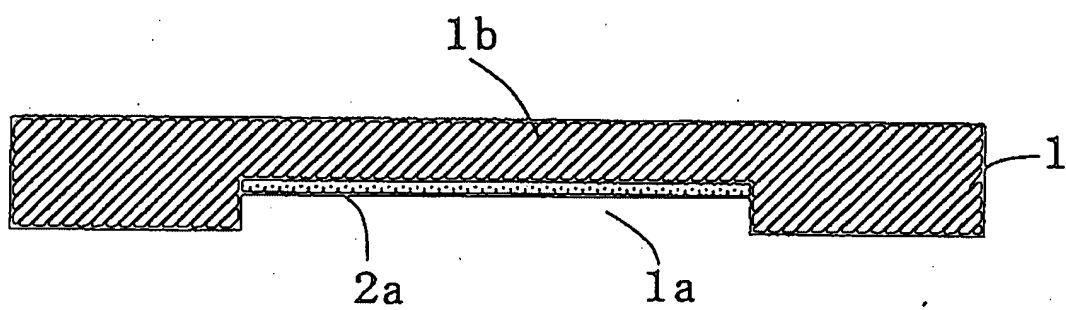
【図 9】 [FIG. 9]



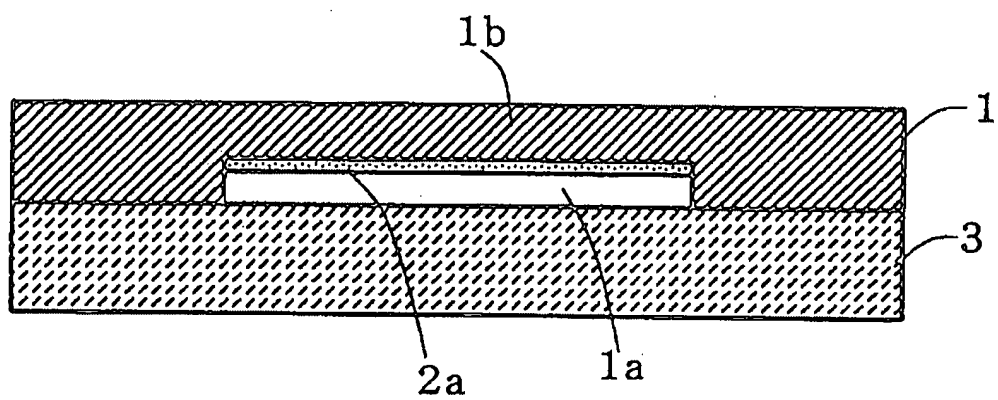
【図10】 [FIG. 10]



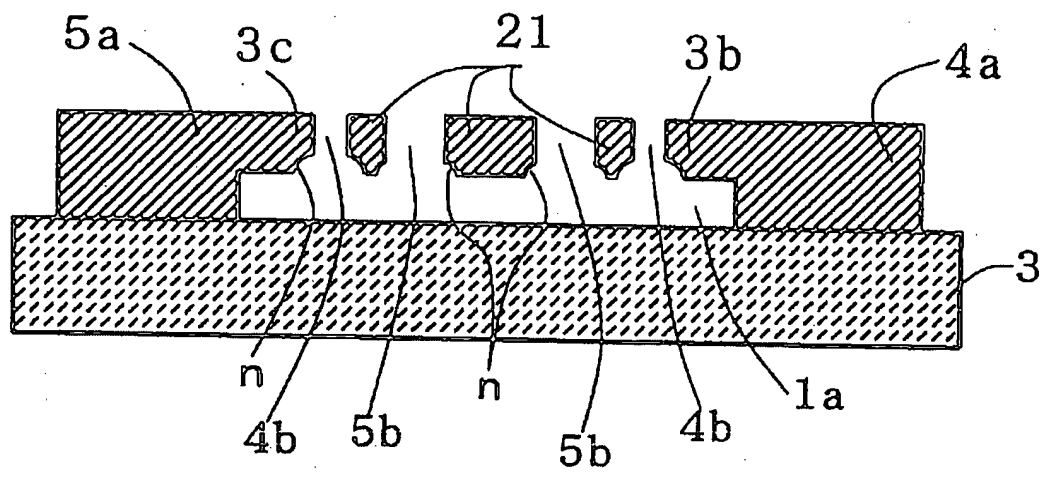
【図 11】 [FIG. 11]



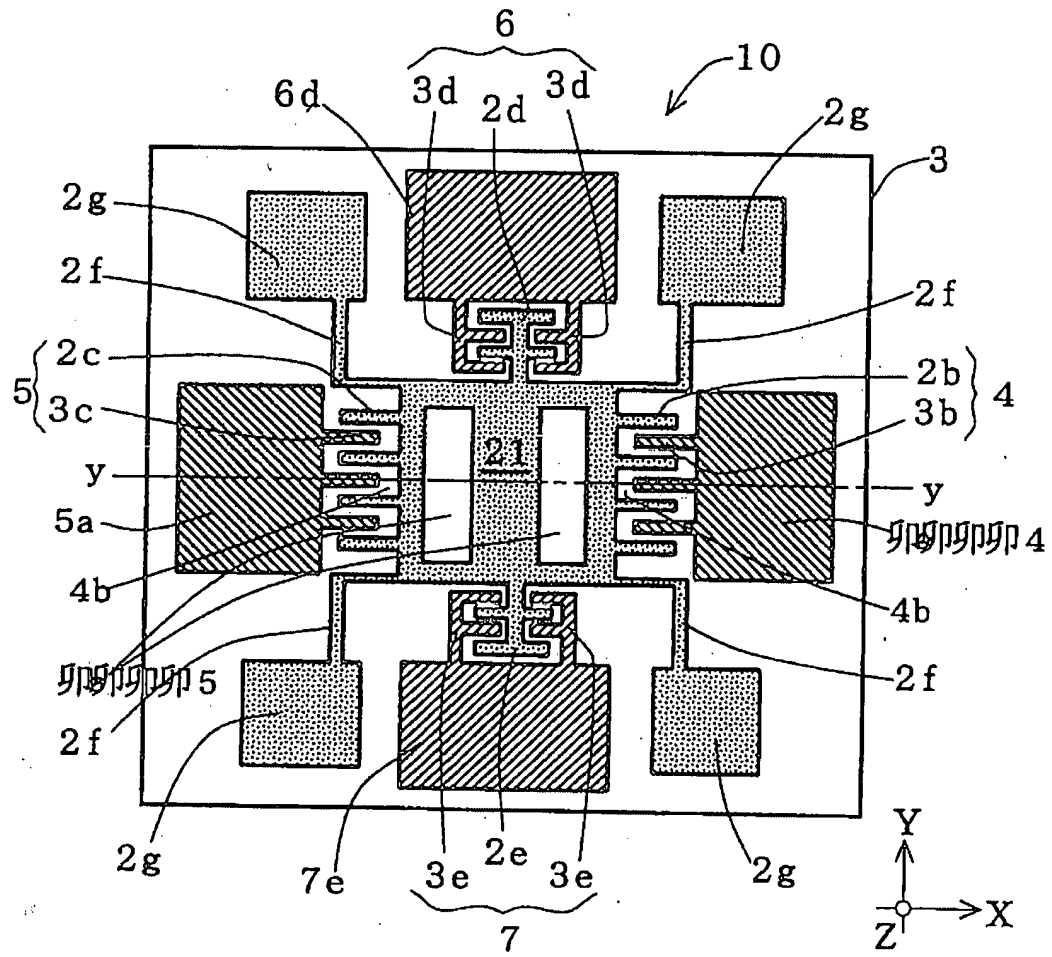
【図 12】 [FIG. 12]



【図14】 [FIG. 14]



【図 15】 [FIG. 15]



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[Name of Document] ABSTRACT

[Abstract]

[Object] To provide a method for manufacturing an external force detection sensor with stable output sensitivity, by preventing the formation of notches by an etching gas.

[Solving Means] A method for manufacturing an external force detection sensor in which sensor elements 3b, 3c, 4a, 5a, 21, etc., are formed by the through dry etching of an element substrate, wherein a conductive material is used for an etching stop layer 2 to be used in the dry etching of the element substrate.

[Selected Figure] Fig. 4